

Pattern Formation and Morphology Evolution in Langmuir Monolayers

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We present a study of how patterns formed by Langmuir monolayer domains of a stable phase, usually a condensed solid or liquid, propagate into a metastable one, usually an expanded liquid. During this propagation, the interface between the two phases moves as the metastable phase is transformed into the more stable one. The interface becomes unstable and forms patterns as a result of the competition between a chemical potential gradient that destabilizes the interface on one hand, and a line tension that stabilizes the interface, on the other. During the domain growth, we found a morphology transition from tip splitting to side branching; doublons were also found. These morphological features were observed with Brewster angle microscopy in three different monolayers at the water/air interface: dioctadecylamine, ethyl palmitate, and ethyl stearate. In addition, we observed the onset of the instability in round domains when an abrupt lateral pressure jump is made on the monolayer. Frequency histograms of unstable wavelengths are consistent with the linear-instability dispersion relation of classical free-boundary models. For the case of dendritic morphologies, we measured the radius of the dendrite tip as a function of dendrite length, as well as the spacing of the side-branches along a dendrite. Finally, we present a model that explains why Langmuir monolayers present these kinds of non-equilibrium growth patterns. The monolayer is modeled as a two-dimensional Navier-Stokes fluid interacting with the subphase through a drag force. In the steady state, the growth behavior is determined by Laplace's equation with specific boundary conditions in the particle density. These equations are equivalent to those used in the theory of morphology diagrams for two-dimensional diffusional growth, where morphological transitions of the kind observed here have been predicted.